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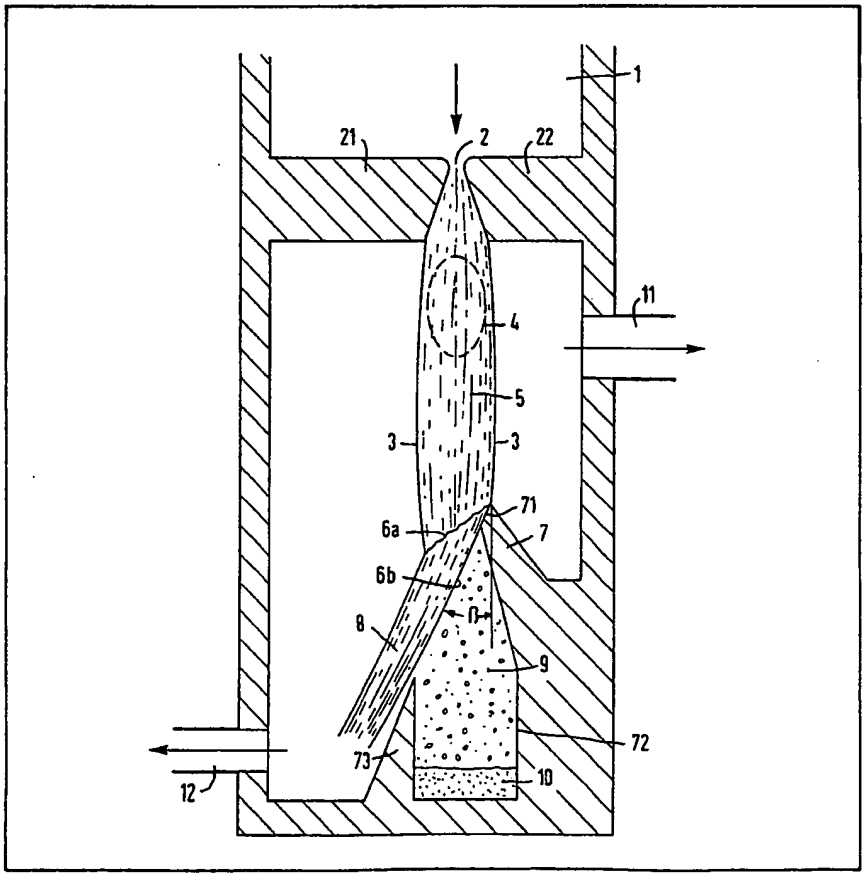
(54) **Separating components of different masses in a gas flow**

(57) A supersonic gas jet (5), e.g. formed by a nozzle 2, containing components of different masses, e.g. isotope compounds, is subjected to a transverse compression shock (6a). The component of lesser mass (8) tends to be deflected and the component of greater mass (9) tends to continue undeflected. The compression shock (6a) may be provided by causing a peripheral part (3) of the gas jet to impinge on a rigid face (71) sharply angled to the jet. A stripper (73) may separate the deflected and undeflected components.

Isotope-specific laser stimulation (4) may be used to convert one of two chemically similar isotope compounds originally present in the jet (e.g. $U^{235}F_6$ and $U^{238}F_6$) to a chemically different compound (e.g. $UF_5$) to enhance the mass difference between the components which are separated by the compression shock.



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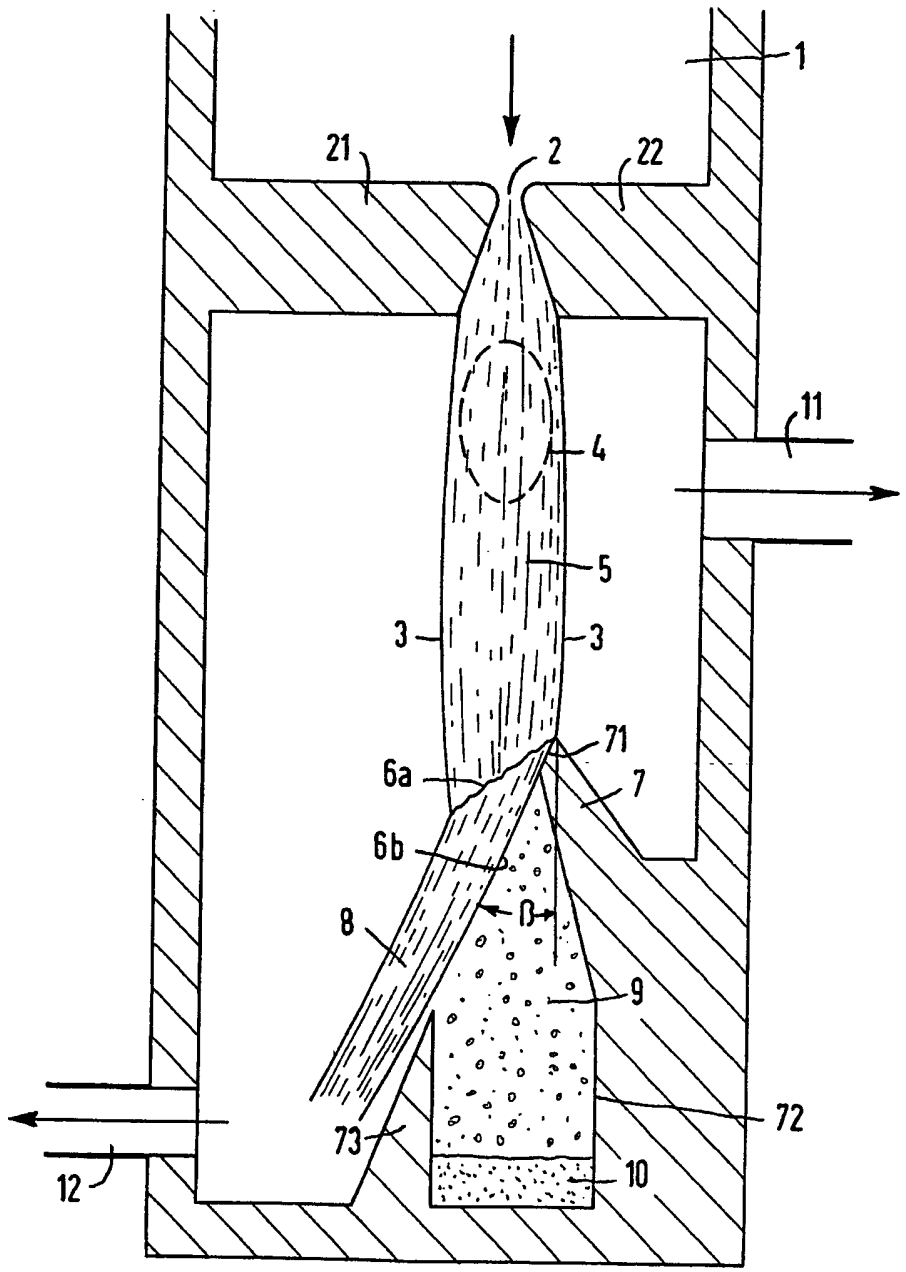

SPECIFICATION

**A method of separating components of different masses carried in a gas flow**

The present invention relates to a method of separating components of different masses carried in a gas flow.

According to the present invention there is provided a method of separating particulate components of different masses, comprising:

forming a supersonic gas jet containing the components of different masses;

subjecting the gas jet to a transverse compression shock such that the component of the lesser mass tends to be deflected, as a result of centrifugal and inertial forces arising from the shock and the component of greater mass tends to continue substantially undeflected (or tends to be deflected less than the component of lesser mass).

Herein, "particle", includes a single molecule, or a plurality of molecules bonded or adhering together, and "particulate" is used accordingly.

Embodiments of the present invention can be applied to the separation of, for example, two chemically similar compounds which contain respective different isotopes of one of the chemical elements making up the compounds, which compounds are carried in a gas flow.

In particular, embodiments of this invention can be applied to the separation of compounds of respective different isotopes of uranium. Embodiments of this invention are appropriate particularly for the separation of isotope compounds, e.g. of uranium, which have been isotope selectively converted–as explained in more detail below. The isotope-selective conversion may be effected through isotope-specific stimulation by means of a laser beam, as explained below. In such embodiments of this invention isotope selective conversion takes place as a preliminary method step.

A number of isotope separation methods have been proposed previously in which the so-called isotope shift in the spectra of uranium compounds is utilised for isotope-specific stimulation of one isotope compound by irradiation with a narrow-band laser beam. In this connection see the German Patent Applications P24 477 62 and 26 59 590 (British Patent No. 1506766 and British Patent Application No. 53681/77 Serial No. 1550049) in which, in particular, an isentropic tension release (expansion; adiabatic expansion) of a gaseous isotope mixture is proposed, whereby the gaseous mixture reaches supersonic speed and is then cooled to temperatures of 30K-50K. This step can provide for particularly successful stimulation of the Q-branch of the $\nu_3$-band in the spectrum of $UF_6$ containing one uranium isotope more or less without affecting $UF_6$ containing the other uranium isotope. The stimulation of just the one isotope compound achieved in this way makes possible, for example, the chemical reaction of the stimulated isotope compound with a simultaneously supplied reaction partner, so that a reaction product, e.g. $UF_5$–a solid substance–is consequently formed. Such reaction products, being primarily aerosol in character, conglomerate or bond together, thus forming particles of greater in size than that of molecules of the isotope compound not taking part in the reaction.

The previously proposed "separator nozzle" process makes use of the mass difference of Uranium 235 vis-à-vis the Uranium 238–when the two isotopes are provided in respective $UF_6$ isotope compounds–for isotope separation. In this process a gas flow carrying the two $UF_6$ isotope compounds (i.e. $U^{235}F_6$ and $U^{238}F_6$) is conveyed and reversed in nozzle-type channels, so that under the influence of centrifugal force and mass moment of inertia respectively a redistribution of the various heavy uranium isotope molecules takes place, so that a gas jet depleted of the desired uranium isotope compound is collected separately from a gas jet in which the desired isotope compound is correspondingly concentrated, with the aid of a mechanical stripper.

In view of the very slight differences in mass between uranium 235 and uranium 238, the degree of effectiveness of a separator step of this type is very low, so that a plurality of such separator steps must be connected in series in order to attain a concentration of 3% uranium 235 such as is required for light water reactors.

The degree of concentration which can be obtained by means of isotope-specific laser stimulation is significantly higher than that obtainable by a separator nozzle step as described above and, circumstances permitting, laser stimulation can yield the desired concentration in one stage only. The important thing here, is that after laser stimulation of $UF_6$ and chemical reaction to form the reaction products (e.g. $UF_5$ and $UF_6$) rapid separation of the reaction product enriched in Uranium 235, for example, from the rest of the gas flow must be produced, since a fluorine exchange between reaction products–e.g. $UF_5$ and $UF_6$–can occur which can reduce the selectivity of this laser stimulation separation. For separation of reaction products utilisation of centrifugal forces produced by gas flow deflection has already been proposed in German Patent Application P26 59 590 (British Patent Application 53861/77 Serial No. 1550049). In that case a gas flow channel was defined by rigid walls. However, this can cause difficulties with apparatus since the flow channel defining walls must be adapted to suit the temperature of the gas jet and there is a possibility of measures for influencing a boundary layer becoming necessary.

Now, embodiments of the present invention provide a method for the separation of particles of differing masses contained a supersonic gas jet, which method does not require rigid walls for the deflection or reversing of gas flow and which can be carried out using substantially simpler devices that heretofore have been used for gas flow deflection.

Preferred embodiments of this invention are employed for isotope separation and, particularly can be used to separate reaction products $UF_5$ and $UF_6$. A transverse compression shock, or several compression shocks, are produced in a gas jet carrying different isotope compounds to give an abrupt change in direction of the jet, so that, as a result of cen-

trifugal and inertial forces which occur lighter components tend to move in a deflected gas jet whilst heavier components tend to continue to move substantially in the original direction and are then collected in a collecting vessel.

Reference will be made by way of example to the accompanying drawing which is a diagrammatic sectional view of apparatus for carrying out a preferred method embodying this invention employed for isotope separation.

A nozzle 2 provides an outlet from a storage chamber 1 (only partially indicated) which holds a gaseous $UF_6$-isotope mixture including a reaction partner (for the isotope compound to be laser stimulated) and possibly a carrier gas. The nozzle 2 is defined by walls 21 and 22. The nozzle 2 is constructed as a slit nozzle and has, by way of example, a radius of curvature at the inlet (on the storage chamber side) of 0.15 mm, a length of 5 mm and an aperture angle of 10°. The nozzle delivers an output gas jet.

In front of the nozzle 2 (below the nozzle in the drawing) a laser beam penetrates the supersonic beam of molecules constituting the gas jet emerging from the nozzle in the manner illustrated. The area of penetration of the laser beam is schematically indicated by a broken-lined ellipse given reference numeral 4. The reaction products e.g. $UF_5$ which are termed as a result of laser stimulation and chemical reaction and which are to be separated by means of the apparatus, form in the region 5 behind or below this area of penetration 4. Further down the beam of molecules peripheral parts 3 of the beam meet a narrow face area 71 at the end of a profile piece 7 secured on or integral with a wall of the apparatus. The profile piece also defines the upper edge of a collecting vessel 72. This face 71 is at an angle $\beta$ of approximately 10-30° to the vertical.

A compression shock 6a (only schematically shown) is formed diagonally through the molecular beam when the narrow peripheral area 3 of the beam meets the face 71, followed by other compression shocks, not illustrated in the drawing, which are caused by the moving gas jet meeting non-moving gas in a chamber 9. A sudden reversing or deflection of the molecular beam is thus caused, thereby to form a diverted gas jet 8 (having a peripheral area 6b). This jet 8 flows freely without any substantial areas of limitation (bounding walls) and is pumped out separately as a condensed gas jet at an outlet 12 in accordance with the known method of pressure recovery. A stripper- or separator wall 73 is formed which separates the pumped out gas jet outlet 12 and reaction product 10 (the heavier product) located in the collecting vessel 72. This separator wall forms a bounding wall of collecting vessel 72. Above the reaction product 10 in collecting vessel 72 a non-moving gas cushion 9 is located into which flows the reaction product 10 from the molecular beam as a result of the inertia of product 10. Reaction product 10 collected in vessel 72 consists of the heavy particles formed in the area 5; the lighter particles, which remain in a molecular state, being carried away in the deflected gas jet 8. The pressure ratio necessary for the occurrence of the isotope-selective reaction is fixed via the return pipe 11. The heavy particles, collected in vessel 10 may be particles of $UF_5$—the lighter chemical reaction product. $UF_5$ forms heavier particles because, as explained above, individual molecules of $UF_5$ tend to bond together, whereas $UF_6$ is present in the form of unbonded individual molecules which constitute the lighter particles. The change in direction in the peripheral area 3 of the molecular beam projected at the narrow face 71 causes a compression shock which passes into the beam and causes a change in direction of the beam below the face. The random or arbitrary change in direction of the beam and the angle of the compression shock can be calculated in a known manner according to the laws of gas dynamics, depending mainly on the type of gas used and the Mach number of the gas. It is also possible for the deflection of the beam to be increased after the compression shock 6 has been released by means of transverse shocks which are released from the non-moving gas 9.

In the apparatus of the drawing the periphery 3 of the jet, below the irradiation area 4, impinges upon a rigid, narrow face area 71 which is at a sharp angle to the axis of the jet. The face 71 forms an upper edge of a boundary of the collecting vessel 72 which forms a chamber below the face 71 (in the original direction of the jet). A lower edge of the collecting vessel (below face 71 in the original direction of the jet) opposite to the upper edge, is formed by a wall part 73, which acts as a stripper and limiting edge for the deflected gas jet 8 which is deflected without the use of guiding walls.

Since, as was mentioned above, the illustration of the apparatus is merely diagrammatic in character, it is certain that there are also other constructional possibilities apparent to those skilled in the art which will bring about the formation of a limitless deflection of the gas flow (with the use of confining or guiding walls).

Thus in an embodiment of this invention used for isotope separation, reaction products of different masses are carried in the gas flow below the selective laser beam stimulation area. These reaction products are separated by flow deflection or reversal, without the use of guiding walls with the aid of a compression shock which is produced when a boundary area of the gas flow meets a narrow face area. The reaction products of smaller mass are than to be found in the deflected part of the flow; those of larger mass continue to stream more or less directly on, into a collecting vessel.

It will be understood that this invention, using a transverse compression shock for the separation of components of different masses has a particularly important application in the field of uranium isotope separation based on the use of $UF_6$ and isotope-selective laser stimulation, as has been described in detail. It is believed, however, that this invention can be of wider application as mentioned above, e.g. the separation of isotopes of other than uranium, the separation of isotopes without selective laser stimulation, or, more generally, the separation simply of components of different masses carried in a gas jet where other methods are, for example, too compli-

cated.

CLAIMS

1. A method of separating particulate components of different masses, comprising:

forming a supersonic gas jet containing the components of different masses;

subjecting the gas jet to a transverse compression shock such that the component of lesser mass tends to be deflected, as a result of centrifugal and inertial forces arising from the shock, and the component of greater mass tends to continue substantially undeflected (or tends to be deflected less than the component of lesser mass).

2. A method as claimed in claim 1, wherein the components of different masses are formed of respective isotope compounds.

3. A method as claimed in claim 2, wherein the isotope compounds are uranium isotope compounds.

4. A method as claimed in claim 2 or 3, comprising forming a supersonic gas jet containing two chemically similar isotope compounds;

selectively converting one of the two similar isotope compounds in the gas jet into an isotope compound of a different chemical nature by means of isotope specific electromagnetic radiation stimulation, thereby to provide in the supersonic gas jet two components formed of chemically different isotope compounds.

5. A method as claimed in claim 4, employing a laser for the isotope specific stimulation.

6. A method as claimed in claim 4 or 5, read as appended to claim 3, wherein the two chemically similar isotope compounds are $UF_6$ isotope compounds and the said two components after selective conversion are formed of $UF_5$ and $UF_6$ isotope compounds respectively.

7. A method as claimed in claim 6, wherein the component of lesser mass comprises molecules of $UF_6$ and the component of greater mass comprises particles made up of molecules of $UF_5$ bonded together.

8. A method as claimed in any preceding claim, wherein the transverse compression shock is provided by impingement of a peripheral part of the gas jet on a rigid face sharply angled to the gas jet.

9. A method of separating particulate components of different masses substantially as hereinbefore described with reference to the accompanying drawing.

10. Apparatus for separating particulate components of different masses carried in a gas flow, comprising:

means for forming a supersonic gas jet containing the components of different masses;

a rigid face, angled sharply to the axis of the gas jet and arranged so that a peripheral part of the gas jet impinges thereupon in such a manner that the jet is subjected to a transverse compression shock whereby the component of lesser mass tends to be deflected, as a result of centrifugal and inertial forces arising from the shock, and the component of greater mass tends to continue substantially undeflected.

11. Apparatus as claimed in claim 10 comprising a collecting vessel arranged for receiving the component of greater mass, wherein the said rigid face constitutes an upstream (from the point of view of the gas jet) edge partially defining an inlet opening of the collecting vessel, a further part of which opening is defined on the opposite side of the opening to the rigid face, downstream of the rigid face, by a stripper and limiting edge for the deflected lighter component, which forms a deflected jet without the assistance of guiding walls.

12. Apparatus as claimed in claim 10 or 11, for separating components of different masses formed of respective isotope compounds, comprising means for forming a supersonic gas jet of two chemically similar isotope compounds, and conversion means for selectively converting one of the two similar isotope compounds in the gas jet into an isotope compound of a different chemical nature by means of isotope specific electromagnetic radiation stimulation, to provide in the supersonic gas jet as it impinges on the rigid face two components formed of chemically different isotope compounds.

13. Apparatus as claimed in claim 12, wherein the conversion means comprise a laser.

14. Apparatus for separating particulate components of different masses carried in a gas jet, substantially as hereinbefore described with reference to the accompanying drawings.

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